order) each involve in their numerator the term $\sin\phi \,.\, \cos\phi$, which vanishes at both the limits 0 and 90 degrees. It is this feature which gives success to the method.

In a second section I have given with some detail the mode of effecting the actual computation of elliptic functions by this means. I have given several formulæ for using trigonometrical tables with the exactness which these calculations require, and I think they will be found handier for the purpose than those usually given in the books; at all events I find them so myself. Some of them are my own, and some are taken, with more or less modification, from Legendre.

In a third section I have stated what has been done with a view to the extension of the method to radicals of a higher index than the square, and to a certain class of differential equations.

It should be understood that these processes only enable us to find the integral from the amplitude. They do not enable us to find the amplitude, modulus, or parameter from a given value of the integral.

April 10, 1862.

Major-General SABINE, President, in the Chair.

The BAKERIAN LECTURE was delivered by WARREN DE LA RUE, Esq., F.R.S., "On the Total Solar Eclipse of July 18th, 1860, observed at Rivabellosa, near Miranda de Ebro, in Spain."

The Lecturer gave an account of the more interesting phenomena of the eclipse, and of the methods employed in observing and recording them; the details of his observations being given in an elaborate Paper bearing the above title. The Lecture was illustrated by a great number of diagrams and models. The photographic images of the eclipse were projected on a screen by means of the electric lamp, and some of the more striking phenomena were imitated by apparatus contrived for that purpose.

The following is an abstract of the Paper :—

The author, for some time previous to the organization of the Astronomer Royal's expedition to Spain, had contemplated making an attempt to photograph the phenomena of the total eclipse of

July 18th, 1860, but as soon as he was informed of the Astronomer Royal's views he agreed to join his party, now known as the Himalaya Expedition, from the name of Her Majesty's ship which conveyed the astronomers composing it to Spain. He attributes much of the success of his operations to the admirable arrangements of Professor Airy in England, and to those concerted with Mr. Vignoles in Spain; for he was able in consequence greatly to increase the extent of his preparations, and to convey a complete temporary observatory fitted up with all the numerous requirements which are essential in astronomical photography. Besides himself, his party consisted of Mr. Beckley of the Kew Observatory, Mr. Reynolds (now Mr. De la Rue's private assistant), Mr. Downes, and Mr. E. Beck, and subsequently the late Mr. Clark. The author expresses himself greatly indebted to these gentlemen for their most efficient assistance.

The party took up their station at a village called Rivabellosa, situated near the town of Miranda de Ebro; the site selected was a thrashing-floor, on which the observatory was erected.

The instruments employed consisted of the Kew heliograph, for the photographic records; an achromatic telescope, by Dallmeyer, mounted on a sort of alt-azimuth stand contrived by the Astronomer Royal, which permitted of an equatorial movement by the ingeniously arranged joint action of two racked radius bars. To this telescope the author fitted a diagonal eyepiece of his own contrivance, which allowed of the use of reflexion from plain glass in the first instance, and then from a portion silvered on the top surface the instant the period of totality commenced. By its means he avoided the perplexity and loss of time occasioned in unscrewing and screwing portions of the apparatus at the most critical period. To these were added a small transit theodolite, three chronometers, two barometers, and several thermometers.

The weather proved so unpropitious that it was with much difficulty the objects of the party could be carried out; and it was only by using every available opportunity that even the Kew instrument could be placed in position.

The geographical position of the site of the observatory was ascertained to be—north latitude 42° 42′, west longitude 11′ 42″·7, elevation above the mean high-water mark 1572·4 feet.

The author made two sketches of the luminous prominences during the period of totality, on paper previously ruled to represent the position-lines drawn on a piece of parallel glass placed in the focus of the eyepiece, which magnified about 60 times. These position-lines consisted of a square calculated to exactly include the lunar disk, and two external squares, one exactly one minute of arc distant from the central square and from the other. The angles of the squares were joined by diagonal fainter lines. The whole system was moveable through an arc of 90°, and its position could be read off on a graduated external circle divided from 10 to 10 degrees. The drawings were by chance made of nearly the exact diameter of the lunar disk in the photographs (4 inches), and proved very valuable in interpreting the phenomena revealed by the latter, as the one could be compared by superposition with the other, and the several prominences be thus identified.

One of the prominences, situated about 30° from the north point towards the east, became visible several minutes before totality, even during the employment of the unsilvered portion of the diagonal reflector. As the sun disappeared the author watched for the so-called Baily's beads, but no such phenomenon occurred, which occasioned no surprise to him, as he had always believed that it arose in all probability from the atmospheric disturbance of an image formed by a telescope wanting in definition.

The author goes on to describe the various appearances presented by the several protuberances, which were not all of a rose-colour, and those which presented this hue were much paler in colour than his previous reading had led him to expect. He is able to speak with considerable certainty on this point, having before the eclipse painted several colours on his drawing-paper, and was thus enabled to compare these directly with the prominences by means of the light emitted by the corona, it being sufficiently great and polychromatic for that purpose. The light of a lamp which was at hand proved not only useless, but was detrimental in making the comparisons. There was a considerable amount of detail, both of form and colour, in the prominences, which the author has shown in two coloured drawings which accompany the paper; these are founded on the original sketches, which are also given in fac-simile, but to some extent corrected by means of the photographs.

That the prominences belong to the sun and not to the moon was rendered evident to the observer by the progressive covering of the luminous prominences on the east in the direction of the moon's motion, and the gradual uncovering of fresh prominences on the west; while prominences situated in a position nearly at right angles to the moon's path shifted their angular position on the moon's edge several degrees during the observations. The prominence which became visible before totality, which the author designates by A, was found to have shifted 3° 25′ on the moon's limb in an interval of about $2\frac{1}{2}$ minutes; it was therefore evident that the region of the moon which at the commencement of the period was in apparent contact with the prominence was at some distance from it at the end; and as the prominence underwent no change during that time, the theory falls to the ground which ascribes the phenomenon of the luminous protuberances to some peculiar action of the moon's edge on light coming originally from the sun.

The author describes the general effect of the eclipse to the unassisted eye. He was particularly struck with the peculiar illumination of the surrounding landscape as the sun became reduced to a small crescent; the shadows of all objects were so sharp and the light so brilliant that it reminded him of the illumination produced by the electric light; at the same time peculiar hues were assumed by the sky and landscape, which suggested the idea that the light of the sun near the periphery is not only less intense than that of the centre, but that it may be different in quality.

No attempt was made to obtain accurate observations of the corona, but nevertheless a few seconds were devoted to this phenomenon. Even several minutes before totality the whole contour of the moon could be distinctly seen; when totality had commenced, the moon's disk appeared of a deep brown in the centre of the corona, which was extremely bright near the moon's limb and appeared of a silvery white, softening off with a very irregular outline and sending forth some long streams. It extended generally to about from 0·7 to 0·8 of the moon's diameter beyond her periphery.

The darkness during the totality was not nearly so great as might have been expected from accounts of previous total eclipses. The illumination was markedly distinct from that which occurs in nature on any other occasion, and certainly was greater than on the brightest

moonlit night, although at the time the light appeared to the author as less bright than what he remembered of bright moonlight. By subsequent trials he was led to conclude that the light during a total eclipse most resembles that degree of illumination which exists in a clear sky soon after sunset, when, after having made out a first-magnitude star, other stars of less brilliancy can be discerned one after another by an attentive gazer. Jupiter and Venus were the only objects the author had time to identify, but some neighbouring observers saw also Castor.

The most important part of the paper treats of the photographic observations. The several preparations are minutely described, and drawings, showing the general arrangements of the observatory, are given. In the focus of the secondary magnifier of the Kew heliograph, two position-wires, crossing at right angles, are fixed at approximately an angle of 45° to a parallel of declination. The object-glass has an aperture of 3·4 inches and a focal length of 50 inches: the primary focal image of the sun at his mean distance is 0·47 inch; but before it is allowed to fall on the sensitive plate, it is enlarged to about 3·8 inches by means of an ordinary Huyghenian eyepiece. The object-glass is so constructed as to ensure the coincidence of the chemical and visual foci; this coincidence is, however, disturbed in a slight degree by the Huyghenian magnifier, which renders a slight adjustment necessary. For ordinary sun-pictures, and those of the several phases of the eclipse except the totality, the aperture was reduced to 2 inches,—a peculiar instantaneous apparatus being employed to regulate the exposure of the sensitive plate.

The driving-clock of the heliograph was, for convenience, kept going during the taking of the partial phases of the eclipse; but it was not really necessary to keep it in motion, because the time of exposure certainly did not exceed the $\frac{1}{50}$th of a second.

The position-wires, by stopping off the sun's light, are depicted in the negatives as white lines crossing the solar disk. It was essential, in order to turn these several pictures to account, to note exactly the time of their being taken, which was done by Mr. Beckley; the clicking noise made by the instantaneous apparatus, when it struck against a stop after releasement, indicating the epoch, which was noted to the nearest half-second. The exact position of the cross

wires was also ascertained by observations of the sun made on each side of the meridian; this was necessary, because, in consequence of the weather, the pole of the heliograph could be only approximately adjusted in position.

Upwards of fifty plates were placed in the heliograph between $11^h\ 28^m$ A.M. and $4^h\ 16^m$ P.M. on July 18th; some before the commencement of the eclipse, and some after. During totality two photographs were obtained. One picture was produced on a plate which was exposed from the exact commencement of totality during the minute succeeding this epoch; the second picture was exposed from about a minute previous to the reappearance of the sun until not more than a second before he became visible. In these pictures the several prominences are depicted with great clearness; and when one negative is superposed on the other, corresponding parts exactly coincide. During the taking of the second photograph, an excusable curiosity on the part of two of the assistants disturbed the telescope twice, so that the prominences have depicted themselves three times; but there was no difficulty in stopping out the images not belonging to either of the three phases thus recorded. The author has moreover turned this accident to account, and estimated the relative brightness of the prominences in comparison with the sun's photosphere; and he considers that they are at least 600 times less brilliant than it. This conclusion has been drawn from the minimum time required by the prominences to depict themselves, which can be made out from the photograph in question.

By means of a new micrometer contrived for that purpose by the author, the several photographs have been measured and discussed. The position-angles of the line joining the sun's centre and the moon's centre, and the distances of these centres for the several epochs of the photographs, have been calculated and compared with the corresponding values calculated by Mr. Farley for the geographical position of the observatory. Other calculations have also been made from the photographs and compared with certain elements of the eclipse calculated by Mr. Carrington. The results show that the photographic method of observing solar phenomena is capable of great exactness.

The nearest approach of the centres of the sun and moon, as ascer-

tained from the photographic measurements, was $11''\cdot8$, calculation giving as a mean $12''\cdot8$. The relative diameter of the moon, that of the sun being taken as unity, as derived from measurements of the photographs, comes out $1\cdot0511$, which is precisely the theoretical number; on the other hand, they tend to show that the diameters at present assumed for the sun and moon, taken conjointly, are about $4''\cdot0$ in excess of the truth.

The paper is accompanied by an extensive series of calculations, which it is not here necessary to describe. Those, however, relating to the measurements of the positions of the luminous prominences on the two totality-pictures have especial interest. These measurements were made in two ways: 1st, the original negatives were measured by the author's new micrometer; 2nd, enlarged positive copies were taken on glass, and the contours of the prominences traced and etched upon the glass, which was afterwards centered on a dividing engine and divided, the divisions being subsequently etched. Copper duplicates were then made of the glass plates, which served to print off diagrams which accompany the paper.

Without describing minutely the measurements, it will suffice here to state that the results go to prove that the luminous prominences must belong to the sun and not to the moon. For example, the change in the angular position of the prominence at a right angle to the moon's path, and designated A in the paper, has been calculated to have been $5° 21'$ for the assumed geographical position of the station; by measurement of the two photographs it is $5° 32'$. The motion of the moon in covering and uncovering a prominence in the line of her path was calculated to have been $92''\cdot8$; by measurement it was found to have been $93''\cdot7$. The accordance of these numbers is so extremely close, that it would be difficult to obtain more convincing proofs that the luminous prominences belong to the sun.

The Society adjourned over the Easter Holidays to Thursday, May 1st.